Feltforsøk med simulert sur nedbør i skog

Field experiments with simulated acid rain in forest ecosystems

I. Soil and vegetation characteristics, experimental design and equipment

Gunnar Abrahamsen
Kristian Bjor
Olav Teigen

Editor SNSF; Finn H. Brække,
Norwegian Forest Research Institute

Director SNSF; Lars N. Overrein

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Authors' address:
Norwegian Forest Research Institute,
1432 Ås — NLH, Norway

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Abstract

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I. Soil and vegetation characteristics, experimental design and equipment

Gunnar Abrahamsen, Kristian Bjor, Olav Teigen

Effects of simulated acid rain on tree growth, ground cover vegetation and on chemical and biological properties of the soil are studied at two sites in southern Norway. The experiments are established in young plantations of Norway spruce, Lodgepole pine, Scots pine and birch, and also in a mature stand of Scots pine.

Field plot size ranges from 15 to 625 m^2 and the number of replicates from 3 to 10. During the growing season 25 or 50 mm/month of simulated rain is applied. "Rain" with pH levels ranging from 6 to 2 is obtained by adding sulphuric acid to well water. Unwatered and limed plots are included in the experiments.

Most irrigation equipment has been specially constructed.

1. Introduction

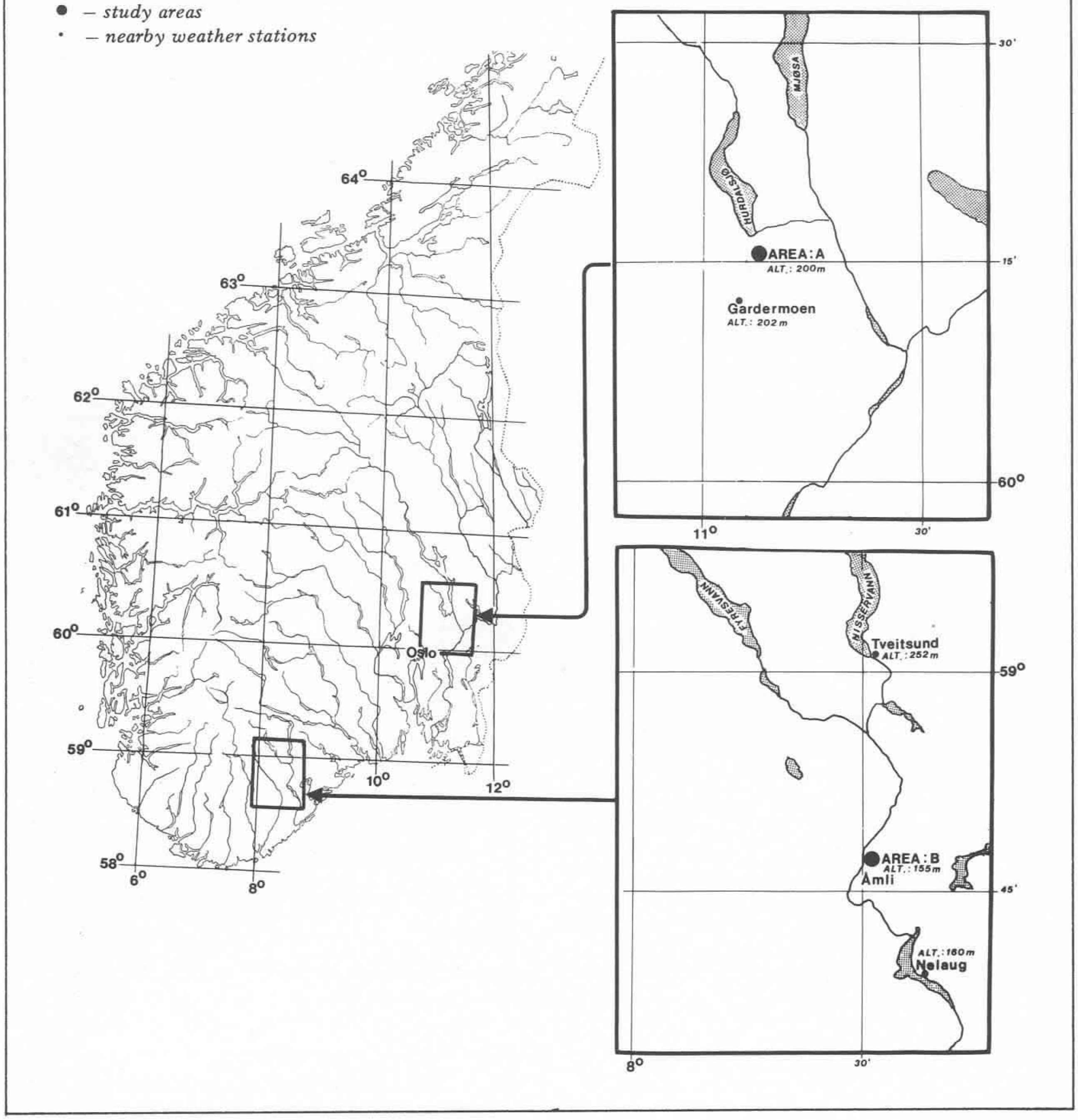
Acid precipitation represents a possible threat to forest ecosystems. Predictions based on theoretical considerations indicate that acid precipitation may reduce forest growth significantly (*Dahl* & *Skre* 1971). However, results of other studies to this date are not consistent (*Jonsson* & *Sundberg* 1972, *Tveite* 1975).

Experiments with soil, on the other hand, have demonstrated that increased leaching of plant nutrients (in particular, calcium and magnesium) is likely to be associated with acid precipitation (*Wiklander* & *Andersson* 1972, *Overrein* 1972, *Wiklander* 1973/74, *Bergseth* 1975).

It is reasonable to assume that if the increased leaching continues, it will result in reduced plant growth. However, deposition of nutrient elements from air pollutants, accelerated weathering of mineral material, and changes in biological processes in soil may counteract the adverse effects of increased leaching. Thus, the ultimate effect of acid precipitation is a very complex problem which requires coordinated plant and soil experiments.

This paper, presenting a description of field experiments, is an introduction to a series of reports from experiments with simulated acid rainfall in forest ecosystems. The aim of these experiments is to elucidate the effect of acid precipitation on tree growth, ground cover vegetation, and on chemical and biological properties of soil. Preliminary results of one of these experiments are given by *Abrahamsen et al.* (1975).

Fig. 1. Location and altitudes of;
● – *study areas*
· – *nearby weather stations*



2. Study areas

Field experiments with trees require relatively large, homogeneous areas. For the simulated rain used in the present study it has also been necessary to have a large supply of fresh water of relatively constant quality. Ground water is much more constant in quality than water from rivers and lakes.

With these factors in mind two areas (A and B) in South Norway have been chosen for the experiments. Study area A is located close to Gardermoen in the county of Akershus. Study area B is located close to Åmli in the county of Aust-Agder (Fig. 1). In area A there have been established three experiments (A-1, A-2, A-3) and in area B two experiments (B-1, B-2).

Table 1. Monthly and annual standard normals (1931–60) of air temperature (Bruun 1967), and precipitation (The Norwegian Meteorological Institute, unpublished information) from weather stations located nearest to the study areas.

	Study area	Weather station	J	F	M	A	M	J	J	A	S	O	N	D	Year	No. of days with frost (daily min. temp. <0°C)
Temperature °C	A	Gardermoen	-6.9	-6.3	-2.3	3.2	9.4	13.6	16.0	14.6	10.0	4.5	-0.6	-3.9	4.3	171
	B	Nelaug Tveitsund x)	-4.3	-4.3	-1.1	3.9	9.6	13.6	15.8	14.5	10.5	5.8	1.5	-1.8	5.3	154
Precipitation mm	A	Gardermoen	59	43	32	48	51	72	94	105	84	86	82	76	832	
	B	Tveitsund	68	48	37	51	60	80	104	129	102	112	118	96	1005	

x) Average for the two stations.

2.1 Climate

Climatic data on the study areas have been obtained from weather stations close to the study areas, run by the Norwegian Meteorological Institute (Tab. 1). The temperature and precipitation information given is therefore assumed to be representative of the study areas. Martonn's humidity indices (e.g. *Hesselman* 1932) for areas A and B are 58 and 64, respectively. The humidity is slightly higher in area B, although both areas are relatively humid.

2.2 Topography, bedrock and soil

Both study areas are flat plains of glaciflucial sediments deposited above the marine limit and overlying Precambrian and Permian crystalline bedrock. The deposits which are dominated by sand (Fig. 2), are exceedingly thick, especially in area A where they are approximately 60 m deep (*Kirkhusmo* 1972). In area A, 80 to 100% of the total amount of material is sand and up to 15% is gravel. Silt constitutes less than 20%. In area B no silt is found. Sand fractions there constitute 50 to 90% and gravel from 10 to 50%. The fraction of particles larger than 0.06 mm was determined by dry sifting, and smaller particles by the hydrometer method as used by *Gandahl* (1952).

All experiments are situated within areas dominated by iron podzolic soil (Tab. 2). The area of experiment A-1 was clear-cut 15-20 years ago. At that time the soil most probably was an iron podzol. The clear-cutting produced a gradual change in the soil profile from podzolic to the semipodzolic soil of today. Chemical ana-

Table 2. Soil chemical characteristics at the experimental sites.

SOIL CHEMICAL PROPERTIES

Experiment	Soil profile	Soil horizon	Approximate sample depth cm	Loss on ignition %	pH (H_2O)	Cation exchange cap. meq/100g	Base saturation %	N in % of oven dry material
A–1	Semipodzol	O	0–3	28	4.4	39	25	0.60
		A_{eh}	3–6	7	4.4	17	15	0.15
		B	9–12	4	4.7	11	7	0.07
A–2	Iron podzol	O	0–3	63	4.3	73	21	0.90
		A_e	3–6	5	4.3	15	8	0.10
		B	9–12	2	5.4	3	6	0.07
A–3	Iron podzol	O	0–3	51	3.9	75	15	0.8
		A_e	3–6	3	4.2	11	4	0.07
		B	9–12	3	4.7	7	3	0.07
B–1	Iron podzol	O	0–4	87	3.7	135	15	1.6
		A_e	4–7	3	4.5	7	5	0.08
		B	10–13	5	5.2	6	2	0.10
B–2	Iron podzol	O	0–7	84	3.9	127	11	1.2
		A_e	7–10	3	4.1	5	4	0.05
		B	13–16	5	4.7	6	2	0.07

lysis of the soil, carried out according to standard procedures used at the Norwegian Forest Research Institute *(Ogner et al. 1976)*, revealed that experimental areas A-2, A-3, B-1 and B-2 are rather similar with regard to basic chemical properties (Tab. 2). The loss on ignition in the humus layer in experiments A-2, A-3, B-1 and B-2 varies between 51 and 87%. The cation exchange capacity varies between 73 and 135 meq per 100 g oven-dried soil and the base saturation is between 11 and 21%. The soil reaction in the humus layer is around pH 4. The chemical properties farther down in the soil are less variable than at the surface layer. At a depth of one meter, the soil pH only ranges between 5.2 and 5.4.

In experiment A-1 variation in chemical properties with soil depth is less than in the soil of the other experiments. This is most probably due to its being the only semipodzolic profile type.

Fig. 2. Grain size distribution at the study areas. Samples are taken at one meter depth.

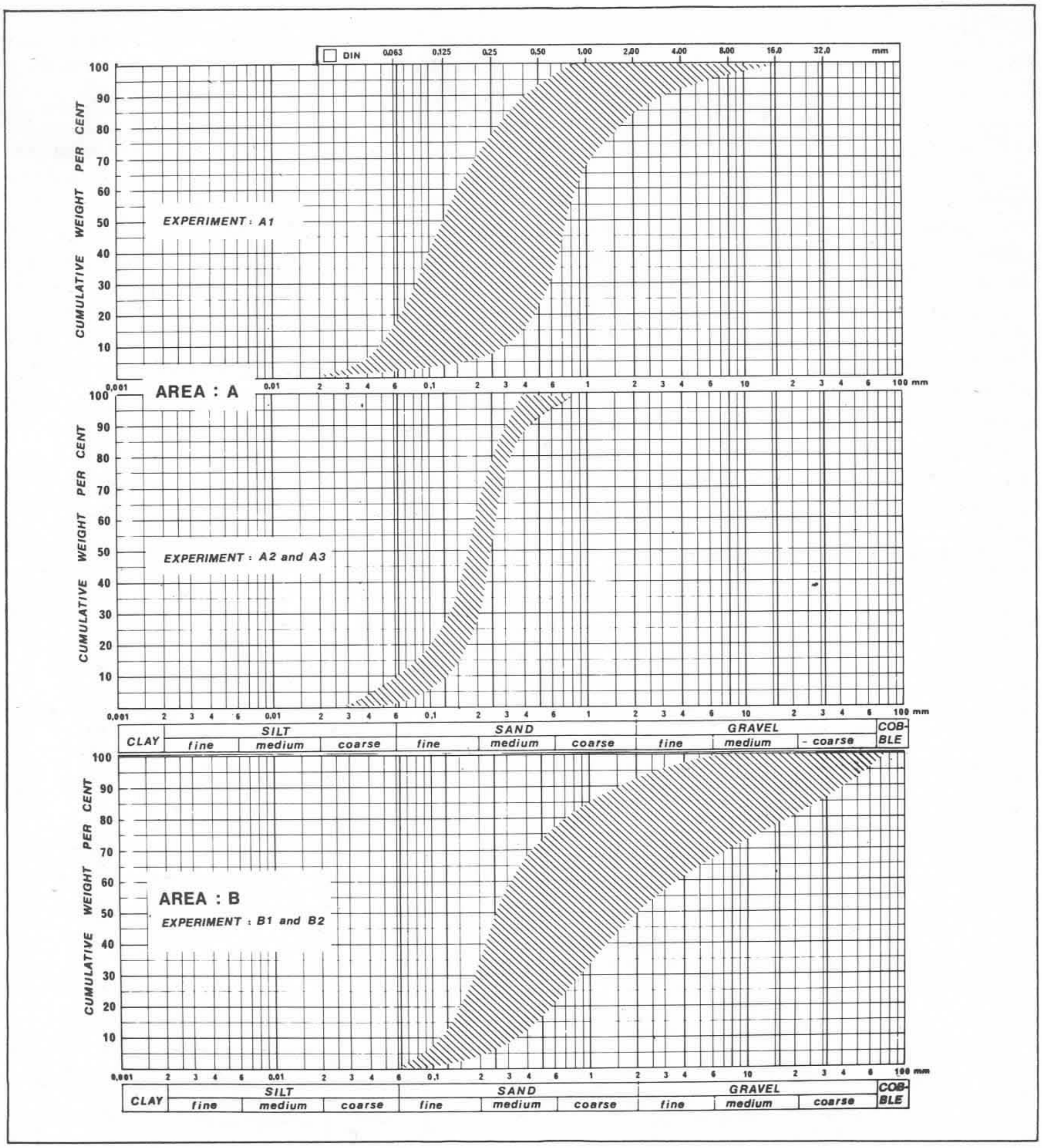


Table 3. Ground water characteristics and amounts of elements deposited per watering.

Experiment	Depth to ground water table m	pH	Conductivity µS/cm	Colour mg Pt/l	Concentration mg/l ($\bar{x} \pm s$) K	Na	Ca	Mg	Fe	NO_3-N
A–1	6 – 7	5.6±0.1	28±2	14±3	0.56±0.05	2.00±0.35	1.65±0.36	0.57±0.10	0.96±0.22	0.08±0.08
A–2, A–3	2 – 4	6.1±0.2	45±4	6±2	0.65±0.08	2.58±0.15	3.69±0.26	0.71±0.04	0.38±0.25	0.08±0.02
B–1, B–2	5 – 6	6.0±0.2	20±2	–	0.32±0.04	1.51±1.17	1.16±0.23	0.33±0.02	–	0.22±0.05
	Monthly "rain" quantity				Deposition per watering kg/ha K	Na	Ca	Mg	Fe	NO_3-N
A–1	25 mm				0.14	0.50	0.41	0.14	0.24	0.02
	50 mm				0.28	1.00	0.82	0.28	0.48	0.04
A–2, A–3	50 mm				0.33	1.29	1.85	0.36	0.19	0.04
B–1, B–2	50 mm				0.16	0.76	0.58	0.17	–	0.11

2.3 Chemical composition of ground water

The chemical composition of ground water has been analysed according to standard methods used at the Norwegian Forest Research Institute *(Ogner et al. 1976).* Measurable concentrations of potassium, sodium, calcium, magnesium, iron and nitrate were found (Tab. 3). Aluminum, manganese, ammonium, sulphate and phosphate were also found but only in scarcely detectable quantities. The highest pH, conductivity and quantity of all cations except iron were found in the ground water used in experiments A-2 and A-3. Except for nitrate, the lowest values were generally found in study area B.

The ground water for experiment A-1 was pumped from the mineral soil layer 3-4 m below the surface of a small peaty deposit. The peat probably causes the higher colouration there than that which exists in the water sources used in experiment A-2 and A-3.

The chemical contents of the ground water imply that irrigation also supplies plant nutrients. Table 3 shows that in experiment A-2 and A-3 almost 2 kg calcium is applied per ha at each watering. Five irrigations per year thus provide an annual application of about 10 kg calcium. The supply of nitrate-nitrogen in area B is approximately 0.5 kg per ha and year.

2.4 Vegetation

Experiments A-1, A-2, A-3 and B-1 are carried out in recently re-established or young forests, and experiment B-2 in a relatively old stand of naturally regenerated Scots pine (*Pinus sylvestris* L.) (Tab. 4).

Table 4. Characteristics of the vegetation of the field experiments.

Experiments		Tree species	Year planted	Average height 1975 (m)	Ground vegetation: Vegetation type	Dominating species
AREA:A	A–1	*Pinus contorta*	1965	3	*Eu-Piceetum Myrtilletosum*	*Deschampsia flexuosa* (L.) Trin.
	A–2	*Picea abies*	1956	4	» »	*Deschampsia flexuosa*
	A–3	*Picea abies* *Pinus sylvestris* *Betula verrucosa*	1975 1974 1974–75	0.2 0.2 -	» »	*Deschampsia flexuosa* *Vaccinium myrtillus* L. *Vaccinium vitis-idaea*
AREA:B	B–1	*Pinus sylvestris*	1968–70	1.5	*Vaccinio Pinetum*	*Vaccinium vitis-idaea* *Deschampsia flexuosa* *Calluna vulgaris* (L.) Hull
	B–2	*Pinus sylvestris*	Natural regeneration, age 85 years	17.0	» »	*Vaccinium myrtillus* *Vaccinium vitis-idaea* *Calluna vulgaris*

Table 5. Treatments, experimental design, number of replicates and plot size of the five field experiments.

Experiment A–1: Free randomization, 3 replicates, plot size 3 by 5 m. Irrigation started August 11, 1972.

Lime applied as $CaCO_3$	No irrigation	Irrigation 25 mm/month pH 5.6	pH 4	pH 3	Irrigation 50 mm/month pH 5.6	pH 4	pH 3
No lime	x	x	x	x	x	x	x
1500 kg CaO/ha				x			
3000 » »		x	x	x			
6000 » »				x			

Experiment A–2: Free randomization, 3 replicates, plot size 150 m^2 (circle) Irrigation started June 28, 1973.
Experiment B–2: Randomized blocks, 10 replicates, plot size 25 by 25 m. Irrigation started August 18, 1975.

	No irrigation	Irrigation 50 mm/month pH 6	pH 4	pH 3	pH 2.5
No lime	x	x	x	x	x

Experiment A–3: Randomized blocks, 4 replicates, plot size 4 by 4 m. Irrigation started June 25, 1974.
Experiment B–1: Free randomization, 3 replicates, plot size 75 m^2 (circle). Irrigation started August 14, 1974.

Lime applied as $CaCO_3$	No irrigation	Irrigation 50 mm/month pH 6	pH 4	pH 3	pH 2.5	pH 2
No lime	x	x	x	x	x	x
500 kg CaO/ha	x	x		x		x
1500 » »	x	x	x	x	x	x
4500 » »	x	x		x		x

The trees of the experiments are dominated by conifers. Experiments A-1, A-2 and B-2 are carried out in plantations of Lodgepole pine (*Pinus contorta* Dougl.), Norway spruce (*Picea abies* (L.) Karst.) and Scots pine, respectively. In experiment A-3, however, birch (*Betula verrucosa* Ehrh.) has been planted, as well as Norway spruce and Scots pine.

The vegetation type of the climax forest in area A is probably the same for all experiments, viz. the *Eu-Piceetum Myrtillus* subassociation. Small patches of *Vaccinio Pinetum* are, however, also found. When the forest of the *Myrtillus* subassociation is cut down the existing ground vegetation is rapidly overrun by *Deschampsia flexuosa* (L.) Trin., which after some years completely dominates the ground flora.

In area B the vegetation type is a *Vaccinio Pinetum*. This association does not undergo the same major changes after clear-cutting. The forest in the area of experiment B-2 burned in 1968, and it still shows some signs of the fire.

3. The experiments

3.1 Experimental design

The basic treatment in the five experiments is watering with dilute solutions of sulphuric acid in quantities of 25 or 50 mm per irrigation in experiment A-1, and 50 mm in the other experiments (Tab. 5). The watering, which is in addition to the natural rain, is carried out once a month. The time used to apply 50 mm "rain" varies from 20 minutes in experiments A-1 and A-3 to 8 hours in experiment B-2, according to the difference in plot size and the capacity of the water pump. In experiment A-1 only 375 or 750 l of water is applied to each plot, whereas more than 31,000 l is used per plot in experiment B-2.

Since the water is supplied to the plots through water pipes lying on or above the ground, watering cannot be carried out in periods with heavy night frosts. This means that the irrigation usually cannot be started before the end of May and has to be finished by the end of September.

In addition to the watered plots all experi-

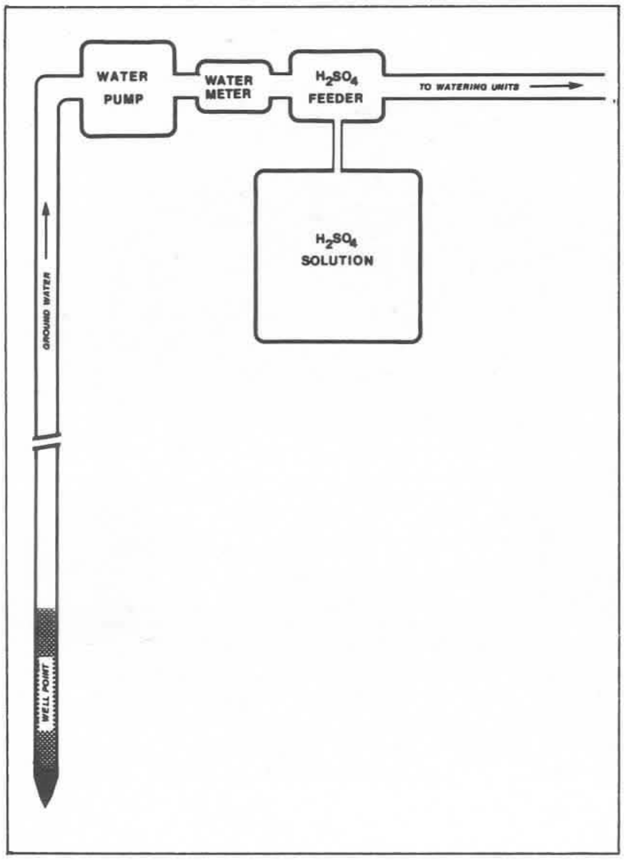


Fig. 3. Supplying system for water and acid to the field plots.

ments include non-irrigated plots serving as controls for the effects of irrigation.

The pH of the control water is not identical in all experiments due to local variation in the ground water quality (Tab. 3). The pH of the irrigation water of various treatments (Tab. 5) is adjusted by sulphuric acid of high quality, containing less than 9 ppm impurities. The quantities of sulphate deposited in each irrigation (50 mm) equal the following approximate values: at pH 4, 3 kg per ha; at pH 3, 24 kg per ha; at pH 2.5, 75 kg per ha; and at pH 2, 240 kg per ha.

Since experiments (*Wiklander* & *Anderson* 1971, *Overrein* 1972, *Wiklander* 1973/74, *Bergseth* 1975) have revealed that acid precipitation is likely to cause increased leaching of calcium and magnesium from soil, liming might be used to counteract the effect of acidification. For this reason the application of crushed limestone is included in experiments A-1, A-3 and B-1 (Tab. 5).

Treatments with both lime and "acid rain" made it possible to establish factorial experiments (Tab. 5). However, several considerations made complete factorial experiments impossible.

Three or four replicates are used in the experiments except for experiment B-2 which has 10 replicates. Two experiments (A-3 and B-2) have randomized block design; the others are freely randomized.

The most extensive experiment (A-3) includes three tree species (Tab. 4), and 240 individual field plots. Only one tree species is included in each of the other experiments, and the total number of field plots appears in Table 5.

3.2 Technical equipment

Rain with varied levels of acidity is simulated by mixing sulphuric acid with ground water pumped from wells (Fig. 3).

The method for mixing acid water differs among the experiments. In experiment A-1 the mixing is carried out in polyethylene tanks supported 5 m above the ground (Fig. 4A). One tank contains the quantity of "rain" applied to one plot. The water is supplied from the tank to watering frames through polyethylene pipes.

In experiments A-2, A-3 and B-1 water-driven chemical feeders (Mesco type 1) add sulphuric acid to water at the ratio 1:100. The desired acidity of the various treatments is therefore obtained by adjusting the concentration of the sulphuric acid supplied to the feeder. The feeder is a small portable unit that is placed just in front of the watering frames.

The stationary feeder used in experiment B-2 is more sophisticated (Wallace & Tiernan. Chemical reagent feeder, Model A-429). It is located near the water pump, and again the desired pH is achieved by varying the concentration of acid supplied. However, this feeder has as an additional feature, the ability to adjust the feed quantity. This is appropriate since small variations in the buffer capacity of the water demand minor adjustments of the quantity of acid used at each watering. This also means that the pH of the simulated rain has to be checked regularly.

The watering frames used in experiments A-1 and A-3 are made of 16 mm o.d. PVC tubes, spaced 20 cm apart. The tubes have holes drilled at 10 cm intervals. Into the holes, 10 cm long capillary tubes (i.d. = 0.5 mm) have been inserted in order to equalize water pressure at each outlet.

In experiments A-2 and B-1, the plots are watered by an especially constructed boom rotated by a small electric motor (Fig. 5C). The watering capacity of the boom increases from

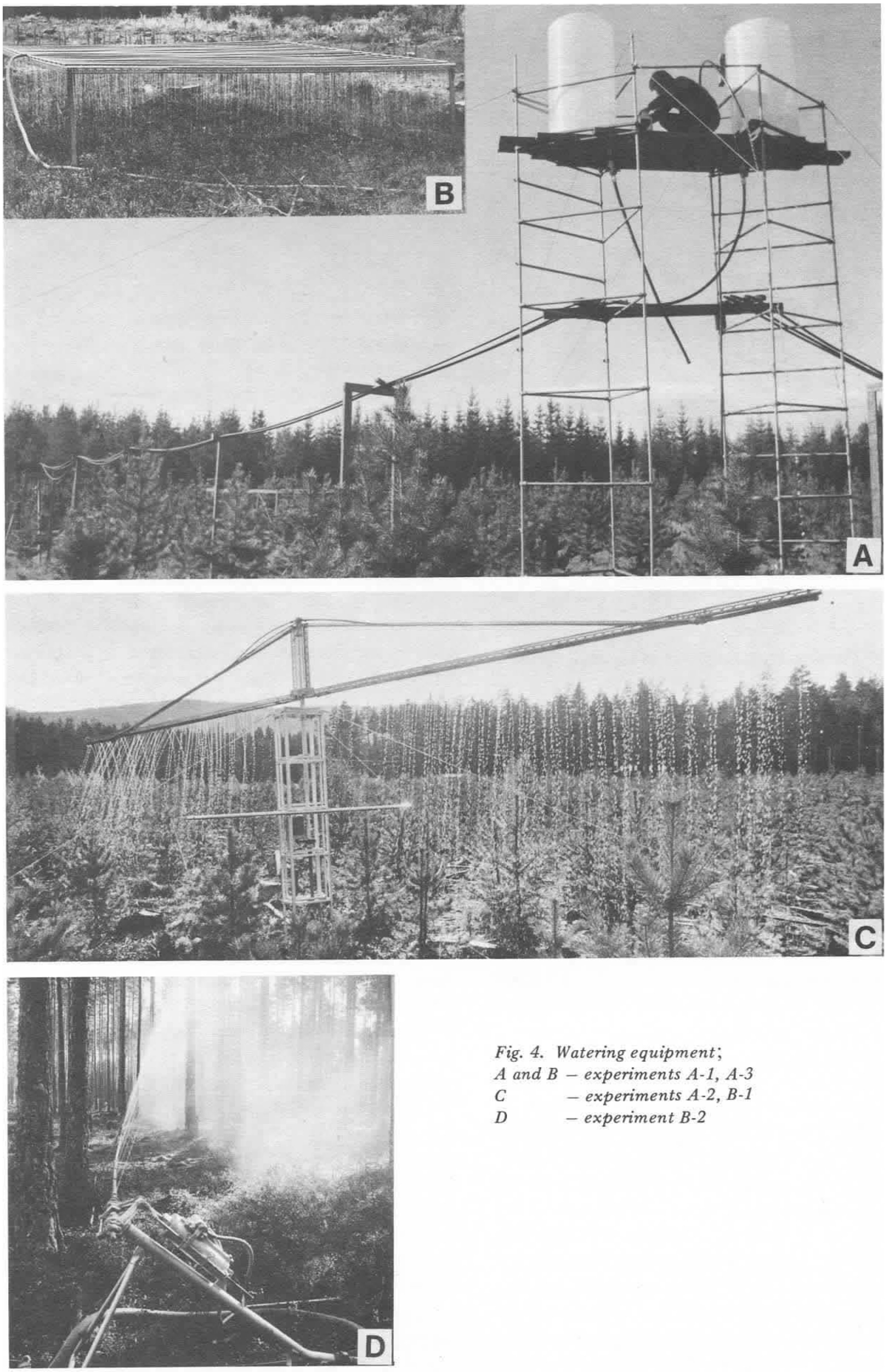


Fig. 4. Watering equipment;
A and B – experiments A-1, A-3
C – experiments A-2, B-1
D – experiment B-2

centre to periphery in order to obtain an even distribution of the "rain". The central telescopic tower makes it possible to adjust the height of the boom according to the tree height. To facilitate transport from one plot to another, the equipment can be broken down into three parts.

Watering in experiment B-2 is performed by a commercial irrigation apparatus (Perrot Hydor-Landregen) made of galvanized iron. The corrosion of the irrigation equipment and the introduction of heavy metals into the simulated rain will therefore be carefully watched during the experiment. Also, efforts will be made to replace the corrodible parts of the irrigation equipment with parts of polyethylene or PVC. In the other experiments all equipment in contact with acid, is made of non-corrodible plastic material.

In experiments A-2, A-3 and B-1 the water is applied from above the tree crowns. In the other experiments only the lower branches are sprayed with the irrigation water (Fig. 4).

4. Discussion

As a consequence of necessary simplifications in the experimental procedures, the results will to some extent be limited in their description of the effects of acid precipitation. The required acidity of the simulated rain has, for example, so far been obtained entirely by means of sulphuric acid. Although the acidity of the natural precipitation is determined largely by sulphur compounds, nitrate may also account for a substantial part of the acidity (*Semb* 1975). Examination of precipitation chemistry data published by *Låg* (1963) and *Goffeng* (1971, 1973) reveals that the concentration of ammonium in precipitation has also increased over the last two decades.

For the period 1955 to 1962 the annual deposition of ammonium and nitrate-nitrogen with precipitation at Ås (59°40'N, 10°47'E, elevation 95 m) was between 2.2 and 3.8 kg per ha. The average annual deposition for the period was about 3 kg per ha, of which ammonium constituted 52% (*Låg* 1963). In the period 1965 to 1971 the deposition varied between 4.8 and 8.1 kg with an average of 6.3 kg per ha and year. The average fraction of ammonium was 57% during this period (*Goffeng* 1971, 1973).

Nitrogen is a limiting factor for tree growth in the northern coniferous forests (e.g. *Tamm* 1975). This factor, together with the precipitation observations, makes it apparent that nitrogen should be added to the simulated rain water. However, as the deposition of nitrogen is related to the acidification of the precipitation, the amount of nitrogen to be applied should be adjusted to the acidity of the simulated rain. At present little information is available regarding the relationship between the nitrogen concentration and pH of incident precipitation. The implementation of experimental fertilization has, therefore, been postponed until further information is available.

Other ions in precipitation, for example, cloride, sodium, potassium, calcium and magnesium have not undergone a significant change in concentration over the last two decades (*Låg* 1963, *Goffeng* 1971, 1973). In southern Norway the concentrations of these elements in precipitation generally is between 20 and 70 per cent of the concentrations in the ground water applied (see Tab. 3). The irrigation, therefore, constitutes a slight fertilization with these elements.

The short time used to apply the simulated rain also implies a deviation from nature. It was feared that the short application time would create a significant loss of water as surface run-off. However, due to the coarse-textured soils (Fig. 2), the infiltration rate is very high and the run-off is usually negligible.

The short application time is mainly a result of the extensive irrigation programme and the use of equipment demanding much manual work. Use of automatic equipment has not been adopted for two reasons. First, the equipment available does not provide an even distribution of the simulated rain. Secondly, this equipment generates much mist, which might drift to adjacent plots.

The "rain" in experiments A-2, A-3 and B-1 is applied from above the trees. This allows studies on leaching from tree crowns and injuries to foliage. These effects cannot be examined in experiments A-1 and B-2 where the "rain" only contacts the lower tree branches.

The strenuous irrigation programme is also the reason for watering only once a month. In our cold climate only five waterings can be carried out during one year. For this reason and also as an attempt to simulate the effect of an input of hydrogen ions over a long period, the very extreme acid treatments have been established. The annual input of sulphate with precipitation in southernmost Norway was in 1973 between 20 and 40 kg per ha (*Dovland et al.* 1975). By comparison, five waterings (50 mm) with pH 4 represent a sulphate input of 15 kg, with pH 3 an input of 120 kg and with pH 2 an input of 1200 kg per ha and year.

Lime has been applied once to the experimental areas. The quantities applied to the plots in experiment A-1 were based on dosages commonly used in agricultural research. In the other experiments the dosages are based on calculation of the theoretical quantities needed to neutralize the amount of acid deposited over a period of five years. Neutralization of acid deposited with natural and simulated precipitation (50 mm per month) and compensation for an estimated loss by leaching require the following approximate quantities: pH 2, 4500 kg CaO per ha; pH 2.5, 1500 kg per ha; pH 3, 700 kg per ha; and pH 4, 300 kg per ha.

The experiments in area A and experiment B-1 have all been established for detailed studies of growth of young trees, ground cover vegetation and biological and chemical processes in soil. The aim of experiment B-2 is mainly to support ongoing comparisons of diameter growth in non-experimental areas supposed to be differently influenced by acid precipitation (*Tveite* 1975). These comparisons have not as yet revealed any differences that can be attributed to acid precipitation. Therefore, experiment B-2 was desired in order to accelerate possible effects caused by acid precipitation and to measure these effects on diameter growth with a higher degree of precision than would otherwise be possible.

5. Summary

The present paper describes soil and vegetation characteristics, experimental design and equipment used in a series of field experiments with simulated acid rain in forest ecosystems. The effects of the "acid rain" studied, include variations in tree growth, ground cover vegetation, and chemical and biological properties of the soil. The experimental sites are located in southern Norway, on plains of glacifluvial sediments, above the marine limit. The dominating soils are iron podzols, and the vegetation types are *Eu-Piceetum Myrtilletosum* and *Vaccinio Pinetum*. The experiments are in young plantations of *Picea abies, Pinus contorta, Pinus sylvestris* and *Betula verrucosa*; and in a mature stand of *Pinus sylvestris*.

Field plot size is from 15 to 625 m². In all but one experiment 50 mm/month of simulated rainfall is applied. With irrigation limited to the essentially frost-free months, this generally allows five applications per year. Ground water, to which sulphuric acid has been added to obtain pH values from 6.0 to 2.0, is used for the irrigation. Additionally, there are unwatered plots and lime-treated plots. Sulphate applied with the acid watering corresponds to a maximum of 1200 kg/ha/year, while 20—40 kg are deposited with the precipitation in the most exposed areas of Norway.

Irrigation equipments are, with few exceptions, constructed especially for these experiments, using non-corrodible plastic materials.

Sammendrag

Feltforsøk med simulert sur nedbør i skog

I. Beskrivelse av jord- og vegetasjonsforhold, forsøksplaner og utstyr.

Rapporten beskriver jord- og vegetasjonsforhold, forsøksteknisk opplegg og benytte utstyr i en forsøksserie som skal belyse virkninger av simulert sur nedbør i skog. Undersøkelsene omfatter virkninger på trærnes vekst, bunnvegetasjon og på jordas kjemiske og biologiske egenskaper. Forsøkene ligger nær Gardermoen i Akershus og ved Åmli i Aust-Agder (fig. 1).

Klimadata fra disse områder er vist i tabell 1. Jordbunnen består av vannsorterte sand- og grusjordarter (fig. 2) for det meste med jernpodsol profil (tab. 2).

Blåbærmark med sterkt innslag av smyle er den dominerende vegetasjonstype ved Gardermoen. I Åmli er det bærlyngmark (tab. 4) Forsøkene utføres i yngre plantinger av gran, furu, vrifuru og bjørk og i et eldre furubestand. Forsøksrutene varierer i størrelse fra 15 til 625m² og det er fra 3 til 10 gjentak (tab. 5).

Grunnvann tilsatt ulike mengder svovelsyre til pH-trinnene 2, 2.5, 3, 4 og 6 brukes som simulert

nedbør. Kalkede og uvannede ledd inngår i forsøkene. Sammenlignet med naturlig nedbør har grunnvannet lavere nitrogeninnhold, men noe høyere konsentrasjon av plantenæringsstoffer som K, Ca, Mg og Fe (tab. 3).

Det meste av vanningsutstyret er bygget spesielt for disse forsøkene (fig. 3 og 4) og er hovedsakelig laget av plast for å unngå korrosjon og ukontrollerte forurensninger.

6. Literature

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